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Water quality cycles in two hill land streams subjected to natural, municipal, and non-point agricultural stresses in the Yazoo Basin of Mississippi, USA (1985–1987)[1]

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Introduction

Instream suspended sediment and bedload materials are, by volume, the largest pollutants in the U.S. (Fowler & Heady 1981). Water erosion removes 1.5 to 2 billion tons of U.S. topsoil each year. The Mississippi River carries 331 million tons of topsoil to the Gulf of Mexico annually (Brown 1984). Sediments from agricultural lands are major contributors and create concern for several reasons:

1) They indicate the loss of valuable topsoil necessary for agricultural productivity;
2) they degrade downstream water resources and carry nutrients and chemical pollutants which adversely affect water quality and aquatic life; and
3) in many cases, they deposit and accumulate in streams and lakes, creating habitat degradation and contamination, navigational difficulties, and shortening productive reservoir life.

Channel instability causes additional difficulties including undercutting of stream banks, headcuts, stream obstruction from vegetation associated with bank failure, and loss of adjoining land and riparian habitat.

Congress, in 1984, directed the U.S. Army Corps of Engineers and the USDA Soil Conservation Service to establish demonstration watersheds to address critical erosion problems on land and in stream channels of hill lands and Piedmont regions across the U.S. Development and testing of systematic watershed soil conservation, channel stability, and flood control programs in these watersheds were mandated. This demonstration project (the Demonstration Erosion Control Project in the Yazoo Basin (DEC Project)) includes many individual structural and non-structural conservation and stabilization efforts combined into a total system of watershed management.

Baseline water quality research began in May, 1985 with emphasis on weekly sampling of Long and Otoucalofa Creeks. Pre-project water quality data are necessary 1) to document the extent of existing water quality problems and 2) to evaluate the effectiveness of construction and conservation measures associated with the project. This report describes water quality conditions during a two year period (1985–1987) for two mixed cover, agrarian streams with erosion problems and evaluates their water quality cycles and contamination problems before implementation of comprehensive watershed treatments.

Study area and methodology

Watershed descriptions and sampling sites

The loess hills of Northern Mississippi were chosen for this research because of a history of large scale erosional sequences with massive gully formation in the uplands and large soil losses from agricultural lands. Since streams in this region have little or no bed controls and the hill land region ends in an abrupt bluffline at the Mississippi River alluvial delta, channels become deeply incised by eroding through soil and subsoil into underlying sands and gravels. These unstable channels are prone to bank caving and loss of adjoining land.

After examining the six watershed catchments in the demonstration project, two were chosen for intensive study. Otoucalofa Creek watershed (29,000 ha) was 21 % row crops, 17 % pasture, and 62 % forest and other uses. The land use pattern in the Long Creek catchment was quite different. Row crops composed 55 %, pasture 33 %, and forest only 12 %. Following an initial exploratory period, seven sites were selected for weekly sampling on Otoucalofa Creek (Fig. 1). Sites 6 and 7 sampled rural tributaries and site 2 monitored Town Creek, a tributary draining the municipality of Water Valley, Mississippi (pop. 4147). Eight sites were selected on Long Creek (Fig. 1). Otoucalofa Creek is a third order stream that flows 37 km east to west in Calhoun, Lafayette, and Yalobusha Counties before it empties into the Yocona River within the upper reaches of Enid Reservoir (113 km² flood pool). Several stream reaches of Otoucalofa Creek (approximately 64 %) have experienced some degree of channelization during the past 10–20 years. Long Creek in Panola County, Mississippi, also a third order stream, flows 29 km east to west and cuts through the loess hills bluffline before draining

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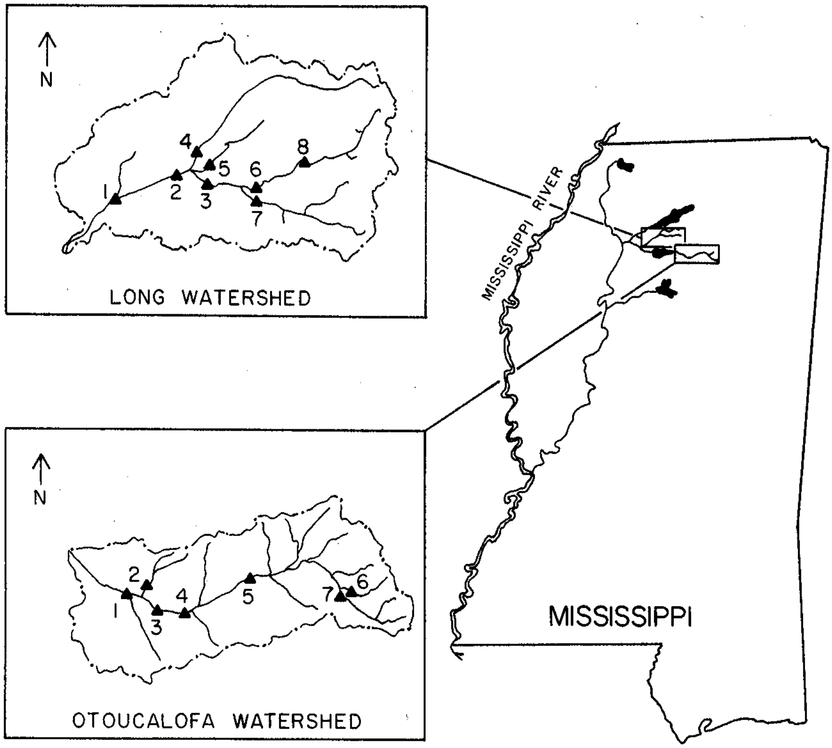

Fig. 1. Map of Mississippi with inserts of Long and Otoucalofa Creeks and numbered sampling sites.

into the Yocona River. The lower third of Long Creek has also been channelized.

Both streams have sufficient gradient to eliminate stagnant pools although riffle-pool sequences are common features. The creeks are bordered by some riparian vegetation for most of their lengths. In its lowest reach Long Creek becomes wider and shallower than Otoucalofa Creek. It also has almost no shading vegetation in this reach. Both channels are deeply incised into the landscape with 2 to 6 m banks that are near vertical in many reaches. Prominent bed features in Otoucalofa Creek include iron-indurated sandstone and clay stills in upper reaches and a sand bottom in lower portions. Prominent bed features in Long Creek and its tributaries are unconsolidated gravel and sandbars.

Sample collection and analysis

Temperature, conductivity, dissolved oxygen, and pH were measured in situ weekly by electronic water quality meters. Total solids, suspended solids, dissolved solids, nutrients and coliforms were analyzed by standard methods (APHA 1975, USEPA 1974). Pesticide and contaminant metal samples from storm flows were analyzed by gas chromatography and atomic absorption spectrophotometry (USEPA 1971). Storm runoff was sampled seasonally at Otoucalofa Creek site 1 (Fig. 1) downstream of Water Valley, Mississippi. Samples were collected in the upper third of the flow depth.

Analysis of variance and Duncan's multiple range tests (Steel & Torrie 1980) were used to test for significant differences between years, creeks and sites for all parameters where assumptions for parametric tests could be met. Nonparametric statistical methods were used for coliform analysis since bacterial concentrations were not normally distributed ($P < 0.01$ level, as determined by Lillifor's test (Conover 1971)). For coliforms, the Kolmogorov-Smirnov two sample test (Conover 1971) was used to test the null hypothesis (i.e., coliform distributions by site or month did not differ significantly ($P = 0.05$)).

Results and discussion

Physical parameters

Physical, chemical, and biological data were grouped by creek, by site and by year (i.e., consecutive 12 month periods). Means and ranges for physical parameters grouped by creek and by year are listed

Table 1. Means and ranges of physical parameters from weekly samples for the 2 years of the pre-project water quality study for Otoucalofa and Long Creeks.

Year	Parameter	Otoucalofa Creek		
		Lower limit	Mean	Upper limit
1	Temperature (°C)	0.4	17.0	28.2
2		3.1	17.7	29.0
1	Conductivity (μmhos · cm^{-1})	19.6	52.3*	126.0
2		10.0	46.8+	192.0
1	Dissolved oxygen (mg · l^{-1})	6.1	9.5*+	16.8
2		0.4	8.0	12.3
1	pH	4.4	6.3*+	7.8
2		5.0	5.9	7.4
1	Total solids (mg · l^{-1})	50.0	122.2*	1886.0
2		48.0	121.8	999.0
1	Dissolved solids (mg · l^{-1})	35.0	56.2*	113.0
2		27.0	55.4	112.0
1	Suspended solids (mg · l^{-1})	0.0	66.0	1845.0
2		0.0	66.4	954.0
		Long Creek		
1	Temperature (°C)	1.8	18.2	31.6
2		3.3	17.6	31.4
1	Conductivity (μmhos · cm^{-1})	24.0	59.6*	122.0
2		15.0	50.7	139.0
1	Dissolved oxygen (mg · l^{-1})	6.4	11.0*	17.9
2		4.8	11.1	17.8
1	pH	4.8	6.8*	8.8
2		4.3	6.8	7.6
1	Total solids (mg · l^{-1})	25.0	152.2*	5697.0
2		9.0	151.2	2941.0
1	Dissolved solids (mg · l^{-1})	39.0	62.3*	138.0
2		9.0	62.6	600.0
1	Suspended solids (mg · l^{-1})	0.0	89.9	5640.0
2		0.0	88.5	2898.0

* Significant difference between creeks.
\+ Significant difference between years within a creek.

in Table 1. Means and ranges are listed by creek and site for each year in Table 2.

All organisms have temperature limits and rates of change in which they may survive. If temperature changes occur gradually, acclimation is possible and, generally, only abrupt changes prove fatal. In temperate zone streams, vegetative canopy buffers extreme temperatures that result from solar radiation; thus, temperature follows a gradual annual cycle of change. During the two year study, temperature followed normal seasonal cycles. No significant differences in mean annual temperature were observed for any site for either creek from year to year, nor were Otoucalofa and Long Creeks different from each other. Site to site means also revealed no spatial differences in temperature in either creek over the two year period. Upper temperature ranges by year were 3.4 and 2.4 °C greater in Long Creek than Otoucalofa Creek, but the extremes observed in either creek were not biologically limiting to regional stream flora or fauna. Although temperature is influenced by solar input, no creek to creek differences were observed. This is noteworthy since Otoucalofa Creek watershed is 62 % forest land compared to 12 % forest on Long Creek and overhanging vegetative canopy reflects those differences. Temperature cycles evidently were influenced more by the earth's ambient temperature and subsurface lateral water exchange than by direct solar input.

Concentration, distribution, and dynamics of oxygen in aquatic systems define the behavior and distribution of most aquatic life. During the study dissolved oxygen rarely declined below 4 mg · l^{-1}, a long term critical minimum concentration (USEPA 1986) for aquatic life (Fig. 2). Long Creek

Table 2. Means and ranges of physical parameters for Otoucalofa and Long Creeks by collection site over the two year observation period (taken from weekly samples).

Site #	Parameter	Otoucalofa Creek		Long Creek	
		Range	Mean	Range	Mean
1	Temperature (°C)	1.8– 28.3	(17.8)	2.1– 29.8	(17.5)
2		5.5– 27.3	(18.2)	2.0– 30.4	(17.6)
3		0.5– 28.0	(17.3)	2.1– 31.4	(17.9)
4		0.5– 27.7	(17.3)	2.2– 30.2	(17.8)
5		0.4– 29.0	(17.2)	2.1– 30.6	(18.0)
6		2.8– 28.2	(16.4)	2.2– 31.6	(18.1)
7		1.3– 27.0	(16.6)	2.0– 30.0	(18.1)
8				1.8– 30.4	(18.1)
1	Conductivity*+ (μmhos · cm^{-1})	12.0– 99.0	(49.4)	22.0– 130.0	(58.3)
2		32.0– 126.0	(75.0)	22.0– 139.0	(57.3)
3		10.0– 67.0	(37.3)	21.0– 107.0	(51.1)
4		12.0– 69.0	(36.5)	15.0– 117.0	(66.6)
5		13.0– 76.0	(40.3)	22.0– 99.0	(56.1)
6		14.0– 119.0	(58.2)	22.0– 91.0	(46.6)
7		13.0– 192.0	(53.4)	20.0– 137.0	(65.5)
8				21.0– 69.0	(40.1)
1	Dissolved oxygen (mg · l^{-1})	6.0– 16.0	(8.8)	6.6– 17.9	(11.2)
2		0.4– 14.4	(8.8)	7.5– 17.0	(11.5)
3		5.7– 15.6	(8.8)	6.7– 17.8	(11.2)
4		6.2– 16.0	(8.9)	6.6– 17.0	(11.0)
5		6.0– 16.0	(9.0)	4.8– 17.5	(11.1)
6		6.1– 13.4	(8.8)	6.4– 16.4	(10.8)
7		3.7– 16.8	(8.5)	5.5– 16.8	(10.6)
8				6.4– 15.6	(10.8)
1	pH+	5.1– 7.4	(6.2)	4.3– 7.6	(6.8)
2		5.2– 7.2	(6.0)	5.7– 7.7	(6.9)
3		4.5– 7.6	(6.1)	5.8– 7.8	(6.9)
4		5.0– 7.6	(6.1)	4.8– 7.7	(6.8)
5		5.0– 7.4	(6.1)	5.6– 7.3	(6.6)
6		5.2– 7.4	(6.1)	5.8– 7.5	(6.7)
7		5.2– 7.8	(6.0)	5.8– 8.8	(6.7)
8				6.0– 7.5	(6.9)
1	Total solids* (mg · l^{-1})	50 –1479	(157.5)	25 –5697	(163.0)
2		51 – 238	(79.8)	54 –2537	(180.6)
3		48 –1207	(145.0)	50 –2043	(159.4)
4		50 –1281	(138.3)	40 –2675	(155.9)
5		51 –1886	(124.3)	9 –2435	(113.4)
6		55 – 614	(99.1)	43 –2941	(140.8)
7		56 –1131	(104.1)	21 –1356	(167.9)
8				39 –1856	(133.4)
1	Dissolved solids*+ (mg · l^{-1})	31 – 112	(53.7)	42 – 95	(65.5)
2		40 – 88	(66.2)	34 – 232	(65.0)
3		37 – 77	(49.4)	44 – 85	(59.3)
4		27 – 82	(47.8)	26 – 97	(67.5)
5		35 – 83	(49.9)	9 – 92	(59.5)
6		40 – 92	(64.7)	43 – 138	(56.8)
7		35 – 113	(61.4)	21 – 103	(68.5)
8				34 – 600	(57.4)
1	Suspended solids* (mg · l^{-1})	0 –1424	(103.7)	0 –5640	(121.2)
2		0 – 165	(13.6)	0 –1917	(91.9)
3		0 –1153	(95.7)	0 –1986	(100.1)
4		0 –1231	(90.5)	0 –2621	(88.3)
5		0 –1845	(74.5)	0 –2398	(53.9)
6		0 – 568	(34.5)	0 –2898	(84.0)
7		0 –1082	(42.5)	0 –1312	(98.3)
8				0 –1822	(76.0)

* Significant differences between sites within Otoucalofa Creek.

+ Significant differences between sites within Long Creek.

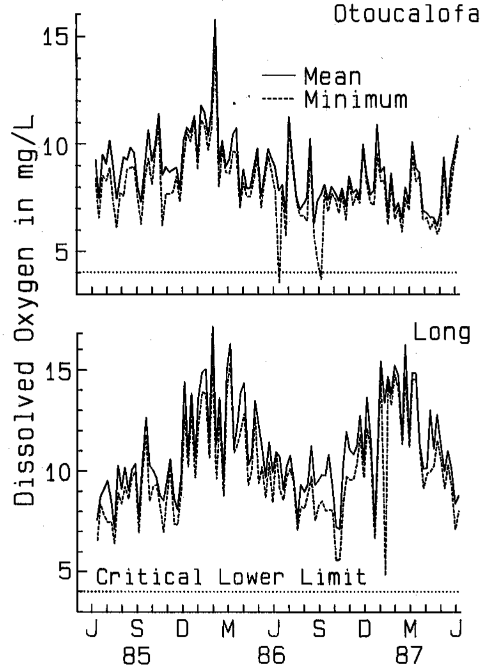

Fig. 2. Weekly dissolved oxygen concentrations for Otoucalofa and Long Creeks.

had significantly greater annual mean dissolved oxygen concentrations than Otoucalofa Creek, and no year to year differences were detected. However, on Otoucalofa Creek, the first 12 month sampling period had significantly greater dissolved oxygen concentrations than the second period. This differences was not important biologically (Table 2), but it may reflect canopy reduction and increased biochemical or chemical oxygen demand from stream bank and bottom disturbances from snag and debris removal on Otoucalofa Creek associated with initial project construction operations.

Soils in the study watersheds are acidic so surface waters tend to be acidic. Long Creek had the lowest (4.3) and highest (8.8) pH of the two creeks during each 12 month sampling period. This range of pH, although extreme, was not common and would not be expected to adversely affect endemic fish species. Although pH values of less than 6 or greater than 9 are suggested as critical limits for maintaining optimum health of warmwater fishes (USEPA 1986), fish species endemic to Mississippi generally are adapted to lower naturally-occurring pH levels. Otoucalofa Creek had a significantly lower mean annual pH than Long Creek. It also exhibited a significant yearly effect with the first year higher than the second. Although Long Creek had no significant changes in pH from year to year, there were significant differences from site to site. In contrast, Otoucalofa Creek had no significant site to site differences in pH.

Total dissolved solids (TDS) is an estimate of all salts and other inorganic and organic materials dissolved in water. Since ionic materials are a major component of TDS, the greater the concentration of TDS, the lower the resistance to electric current and, therefore, the higher the conductivity. Long Creek had significantly greater annual mean TDS than Otoucalofa Creek, but neither creek had any year to year differences. Otoucalofa site 2 on Town Creek, a tributary which drained Water Valley, Mississippi, had significantly greater mean TDS than other sites. Long Creek exhibited site to site differences in TDS, but these differences followed no discernible spatial pattern. As expected because of TDS concentrations, Long Creek had significantly greater annual mean conductivities than Otoucalofa Creek.

Since freshwater fish constantly absorb water because of the strong osmotic gradient in which they live, they must also expel large quantities of water while retaining essential ions. When ambient concentrations of dissolved materials are drastically altered, fish die because they cannot maintain an osmotic balance. United States Environmental Protection Agency (1986) regulations indicate that total dissolved materials should not be altered so that characteristic populations of aquatic organisms are significantly changed. MACE (1953) and ROUNSEFELL & EVERHART (1953) established an upper tolerance of TDS for fish at 5,000 to 10,000 $mg \cdot l^{-1}$ However, the optimum concentration of TDS for fish health and diversity was estimated to be between 169 and 400 $mg \cdot l^{-1}$ (HART et al. 1945). Mean TDS never exceeded these optimal concentrations in either stream.

Total and suspended solids are determined by soil structure, land use, rainfall/runoff, drainage patterns, and channel erosion. Total solids (TS) and its major component, suspended solids, adversely affect aquatic organisms by mechanical abrasion which damages delicate organisms or tissues (e.g. fish gills). As suspended solids settle, the blanketing effect of deposition kills invertebrates and may kill or damage fish eggs and larval fishes. The organic portion affects chemical characteristics of water by contributing to oxygen depletion. Solids may also act as carriers for toxic pollutants such as pesticides (USEPA 1986) since the inorganic fraction often has large electrostatically charged surfaces.

Mean annual TS were significantly greater in Long Creek than in Otoucalofa Creek; however, no significant difference was found between the creeks for suspended solids. The lack of difference in suspended solids between creeks is noteworthy since 55% of Long Creek watershed is in rowcrops and 62% of Otoucalofa Creek watershed is forested. Neither creek demonstrated significant yearly differences for total or suspended solids nor were any significant site to site differences found. Standards for maximum allowable total or suspended solids for warm water fish production have not been established; however, 80 to 100 mg · l is accepted as the maximum amount for optimal growth. Although mean concentrations of TS slightly exceeded this 80 to 100 mg · l^{-1} limit, no visible signs of stress were noted in captured fish. If concentrations experienced during high flows (Fig. 3) were sustained over longer periods, fish and other aquatic fauna would have incurred detrimental effects.

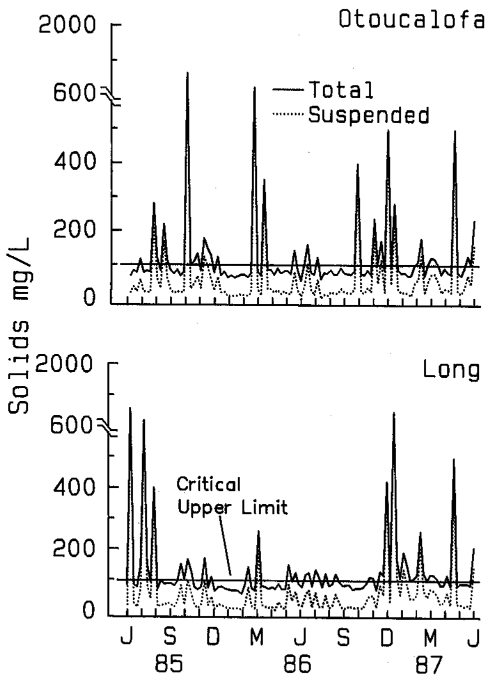

Fig. 3. Weekly and critical total and suspended solids concentrations for Otoucalofa and Long Creeks.

Chemical parameters

Phosphorus is scarcer than most organic building blocks and is rapidly taken up by aquatic organisms. Thus, it is usually a limiting nutrient for aquatic productivity (Cole 1975). Although phosphorus is often limiting in aquatic systems, excessive amounts from agricultural runoff or municipal wastewater cause eutrophication problems. All annual mean phosphorus parameters except total orthophosphate (PO_4-P) indicated significant yearly differences in both creeks. These differences followed no regular fluctuation pattern from year to year in sites on Otoucalofa Creek. In contrast, Long Creek showed consistent decreases in phosphorus from sampling year 1 to sampling year 2. Site 1 on Otoucalofa Creek exhibited significantly greater concentrations of phosphorus compounds than other sites (Table 3) which were not statistically different from each other. This divergence was expected since site 1 was located downstream from the Water Valley sewage treatment facility's discharge outlet. Site 4 on Long Creek had significantly greater annual mean concentrations of filterable orthophosphate than other Long Creek sites. Higher concentrations were likely linked to large tracts of row crops and pasture above site 4.

Phosphorus did not reach concentrations sufficient to cause oxygen-depleting algal blooms. Phosphorus stimulation of phytoplankton occurred at site 1 on Otoucalofa Creek during spring and summer months, attracting large schools of forage fish (gizzard shad, *Dorosoma cepedianum*). These fish were heavily exploited by largemouth bass (*Micropterus salmoides*) and channel catfish (*Ictalurus punctatus*), two important area game fishes (Knight & Cooper 1987). As a result of this readily available food source, largemouth bass had an estimated growth rate of 0.45 kg · year^{-1}. This growth rate is comparable to rates sought in managed fertilized farm ponds and about twice the 0.24 kg · year^{-1} average for waters in the Southeastern United States (Carlander 1977).

Otoucalofa Creek had a significantly greater mean concentration of nitrate-nitrogen and ammonium-nitrogen than Long Creek (Table 3). Otoucalofa Creek's nitrogen output was relatively constant since the major source was the Water Valley sewage treatment facility. Site 1 on Otoucalofa Creek, directly downstream of the sewage treatment lagoon, had a significantly greater mean ammonium-nitrogen concentration than all other sites. Both sites 1 and 2, municipal

Table 3. Means and ranges of chemical parameters for Otoucalofa and Long Creeks by collection site over the two year observation period.

		Otoucalofa Creek		Long Creek	
Site	Parameter	Range	Mean	Range	Mean
1	Filterable orthophosphate	0.034–0.577	(0.194*)	0.009–0.723	(0.051)
2	($mg \cdot l^{-1}$)	0.008–0.219	(0.025)	0.009–0.465	(0.050)
3		0.008–0.232	(0.024)	0.009–0.298	(0.036)
4		0.006–0.152	(0.020)	0.008–0.530	(0.055^{+})
5		0.006–0.085	(0.015)	0.008–0.342	(0.033)
6		0.006–0.222	(0.017)	0.014–0.251	(0.037)
7		0.006–0.144	(0.013)	0.006–0.504	(0.046)
8				0.016–0.229	(0.036)
1	Total	0.006–0.504	(0.147*)	0.003–0.087	(0.015)
2	orthophosphate	0.003–0.195	(0.018)	0.003–0.097	(0.014)
3		0.002–0.044	(0.008)	0.003–0.035	(0.009)
4		0.002–0.018	(0.007)	0.005–0.457	(0.028)
5		0.002–0.012	(0.006)	0.003–0.226	(0.016)
6		0.003–0.147	(0.010)	0.003–0.032	(0.010)
7		0.003–0.035	(0.007)	0.003–0.082	(0.013)
8				0.003–0.041	(0.010)
1	Total phosphorus	0.079–0.949	(0.282*)	0.031–3.950	(0.163)
	($mg \cdot l^{-1}$)2	0.021–0.433	(0.061)	0.031–2.370	(0.155)
3		0.029–0.580	(0.084)	0.035–1.260	(0.124)
4		0.028–0.620	(0.059)	0.028–2.255	(0.142)
5		0.026–0.600	(0.069)	0.026–1.475	(0.095)
6		0.021–0.463	(0.060)	0.038–1.005	(0.100)
7		0.024–0.565	(0.059)	0.031–0.925	(0.151)
8				0.038–0.715	(0.101)
1	Ammonium-Nitrogen	0.071–2.646	(0.674*)	0.000–0.650	(0.120)
2	($mg \cdot l^{-1}$)	0.004–0.942	(0.131)	0.000–0.744	(0.119)
3		0.014–0.586	(0.101)	0.000–0.350	(0.100)
4		0.012–0.600	(0.107)	0.000–2.868	(0.149)
5		0.006–0.594	(0.114)	0.000–0.638	(0.092)
6		0.002–1.875	(0.130)	0.020–0.541	(0.118)
7		0.006–1.110	(0.121)	0.008–0.569	(0.114)
8				0.018–1.920	(0.173^{+})
1	Nitrate-Nitrogen	0.007–0.644	(0.223*)	0.014–0.598	(0.136)
2	($mg \cdot l^{-1}$)	0.140–0.798	(0.582)	0.020–0.552	(0.144)
3		0.031–0.323	(0.111)	0.029–0.470	(0.145)
4		0.025–0.373	(0.095)	0.024–1.220	(0.201^{+})
5		0.019–0.638	(0.072)	0.015–0.868	(0.189^{+})
6		0.009–0.183	(0.047)	0.030–0.316	(0.144)
7		0.012–0.472	(0.075)	0.008–0.525	(0.084)
8				0.013–0.225	(0.104)

* Significant differences between sites within Otoucalofa Creek.
$^{+}$ Significant differences between sites within Long Creek.

runoff sites, had significantly greater concentrations of nitrate-nitrogen than other sites. Sites 4 and 5 on Long Creek were significantly greater in nitrate-nitrogen than other sites on the creek, perhaps, as in the case of phosphorus, because of large areas of pasture and rowcrop agriculture.

Although ammonia (NH_3) is extremely toxic to fish (WEDEMEYER et al. 1976), its concentration is both temperature and pH dependant. As pH declines, ammonia is converted into relatively nontoxic ammonium (NH_4^+). Since pH values were acidic during the 2 year study, little or no toxic unionized ammonia was present. Nitrogen forms never reached concentrations which cause adverse phytoplankton blooms or produce toxic effects on aquatic organisms.

Biological

Means of indicator bacteria denisties by year and by site for Otoucalofa and Long Creeks (Fig. 4) showed that warm-blooded animal contamination is a major pollution problem in these streams draining mixed cover watersheds. In addition, the concentration of humans and domesticated pets at Water Valley was a major source of contamination in Otoucalofa Creek.

Contamination levels in both streams exceeded contemporary water quality criteria for primary contact (swimming or bathing) at all sites during most of each year. Maximum allowable concentrations are 240 organisms per 100 ml for total coliforms (TC) and 200 organisms per 100 ml for fecal coliforms (FC) (Harms et al. 1975). Monitoring contamination sources is difficult since total coliform enumeration is general in nature and several streptococci are ubiquitous in soil and aquatic environments (Faust 1982). The best method for separating humans from other warm-blooded sources of contamination may be fecal coliform (FC): Fecal streptococci (FS) ratios over time. FC/FS ratios of less than 1.0 indicate warm-blooded animal pollution while ratios of 4.0 or more suggest domestic waste (Geldreich 1976, Baxter-Potter & Gilliland 1988). FC/FS ratios exceeded 1.0 on 82 of the 280 samples (29 %) from Otoucalofa Creek. FC/FS ratios exceeded 4.0 in 6 % of the samples. In Long Creek, 38 % of the samples had a ratio greater than 1.0 while 13 % had a ratio greater than 4.0. The second year of the study had the greatest incidence of FC/FS ratios above 1.0. Fifty percent of the FC/FS ratios for Long Creek for year two were greater than 1.0. These ratios suggest that warm-blooded animal pollution is common in the streams and that domestic wastes are occasionally a source of pollution.

Since both runoff and rising water levels flush stream borders and tributaries where wildlife and livestock routinely defecate, coliform densities and rainfall-related parameters were examined for possible relationships. Contamination was not predictably related to rainfall, discharge, suspended sediments or other runoff-related parameters nor could it be correlated to measured chemical or physical parameters. Storm samples showed that coliform densities increased dramatically as water level rose and flushed sand bars and channel banks; however, comparisons of coliform densities and hourly records of stage at site 1 on Otoucalofa Creek did not show predictable relationships. These results agreed with research by Robbins et al. (1972) who reported that bacteriological concentrations in streams with agricultural watersheds greatly exceeded quality limits for recreation. Although coliform densities were overshadowed by storm events, Robbins et al. (1972) could not accurately predict bacterial pollution from water quality parameters.

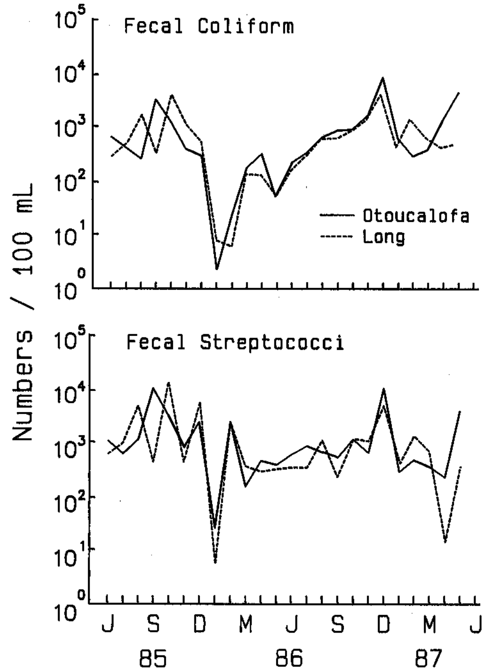

Fig. 4. Monthly fecal coliform and fecal streptococci counts (# / 100 ml) for Long and Otoucalofa Creeks.

No significant differences in coliforms were found between the two creeks although there was greater human population density near Otoucalofa Creek. Not only were fecal coliform and fecal streptococci concentrations for the two creeks similar, seasonal and event marked trends were parallel (Fig. 4). Although no significant differences were found between sites in either stream, some trends emerged when individual collection dates were examined. During runoff periods, Otoucalofa Creek sites 1 and 2, downstream of the town of Water Valley, produced greater coliform densities than other mainstream sites. During these periods, site # 6, a tributary which flowed through cattle pasture, had greater coliform densities than other rural stream sites.

All three coliform indicators showed significant seasonal differences. Although coliform densities could not be correlated to discharge over time, differences in successive seasons appeared related to the occurrence of major rainfall events. For example, fall, 1985, had significantly greater coliform densities, than the preceding summer or following winter (Fig. 4). Summer, 1985, had the lowest recorded rainfall of the year. There were three rainfall-runoff events in September and October followed by a dry winter with no runoff events. Winter of 1986, particularly December, had significantly greater coliform densities than the remainder of the 12 month period. More than 35 cm of rain fall in November and December.

Background concentrations of coliforms during normal flows showed continuing contamination and survival of enteric bacteria from warm-blooded animals and indicated a potential health hazard. Much of this contamination could not be controlled since stream borders were inhabited by wildlife. Contamination from cattle, domestic pets, humans, and indigenous soil and water coliform species compounded problems.

Storm events

Ten storm events covering all seasons were sampled at Otoucalofa Creek, site 1. Storms ranged from small events accompanied by less than one meter increase in stage to a "bank full" event which produced a hydrograph peak of 4.7 m. Several parameters exhibited repeatable trends, regardless of storm size or season. Temperature decreased temporarily from influx of cooler rain water. Conductivity and dissolved solids decreased by 30 to 50 percent from dilution. No significant changes were noted in dissolved oxygen or pH. Several residual pesticides were routinely encountered in samples taken during the rising portion of the storm hydrograph. These pesticides, including DDT, DDD, DDE, heptachlor, lindane and dieldrin, were used in farming practices before being banned in the 1970's. Concentrations were generally less than $1.0\,\mu g \cdot kg^{-1}$ (ppb) and never approached harmful levels. Arsenic and mercury, two metals traditionally used in herbicides and seed treatments and which occur naturally, also appeared routinely in storm flows, Arsenic and mercury concentrations, which peaked between 5 and $15\,\mu g \cdot kg^{-1}$ in storm flows, were within the range of natural background or historical contamination concentrations.

Storm event sampling highlighted the importance of ground cover in prevention of erosion. The greatest concentration of total solids in Otoucalofa Creek, $3879\,mg \cdot l^{-1}$ (ppm), was measured on 23/4/85 during a mediuum-sized storm with a maximum gauge height of 2.3 m. During this season, land preparation for planting exposes freshly tilled soil to erosion and runoff. Total solids concentrations during this storm exceeded concentrations measured in storms of twice the magnitude but sampled during other seasons. A similar event produced nearly $6{,}000\,mg \cdot l^{-1}$ total solids in Long Creek. Observations indicated that the suspended sediment load carried by Otoucalofa Creek was only a fraction of the total sediment load carried during storm events. Typically, as water receded following a storm, new sand deposits were observed on streambanks, bars and behind bridge pilings.

Summary

This study monitored water quality cycles and compared two bluffline streams, one of which passed through the town of Water Valles, Mississippi. In spite of land use differences in the two watersheds, temperature and suspended solids were not significantly different in the creeks. Phosphorus and nitrogen concentrations at Otoucalofa Creek site 1 were significantly higher than all other sites in either creek because this site received nutrient rich drainage from Water Valley and the town's sewage lagoon effluent. The resulting nutrient stimulation of plankton attracted large numbers of forage fish which were, in turn, heavily exploited by game fish. Concentrations of physical or chemical parameters measured during normal flow conditions were not great enough to be detrimental to aquatic life.

Coliform indicators showed that contamination levels in both creeks routinely exceeded clean water standards for primary contact. Although there was a greater human population near Otoucalofa Creek, there were no significant differences in contamination levels between the two creeks. Statistical seasonal differences in coliforms were related to the presence or absence of rainfall. Background concentrations showed continuing contamination and survival of coliforms from warm-blooded animals.

Storm flows flushed very low concentrations of residual pesticides and arsenic and mercury from agricultural lands. Suspended sediment from storm relat ed runoff produced peak concentrations of nearly $6{,}000\,mg \cdot l^{-1}$ which constituted only a small percentage of total load carried by storm flow. Under normal and

low flow conditions, water quality was considered good in the two streams with the exception of coliform contamination. Nutrient additions from municipal wastewater enhanced stream biotic productivity because of the oligotrophic nature of the streams.

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